

# The DarkLight Experiment: Searching for Dark Forces at the JLab FEL

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Massachusetts  
Institute of  
Technology



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# Outline

- 1 Motivation
- 2 DarkLight Overview
- 3 Design Overview
- 4 Software Development
- 5 Status and Summary



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# What is DarkLight?

- DarkLight is a proposed experiment:
- Searching in the lowest dark photon mass regime: 10-100 MeV/c<sup>2</sup>



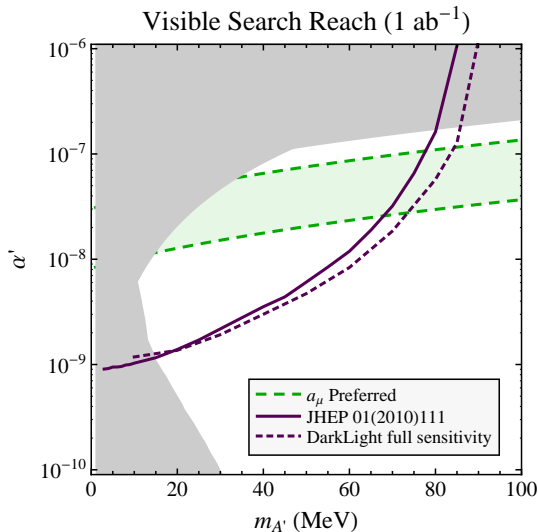
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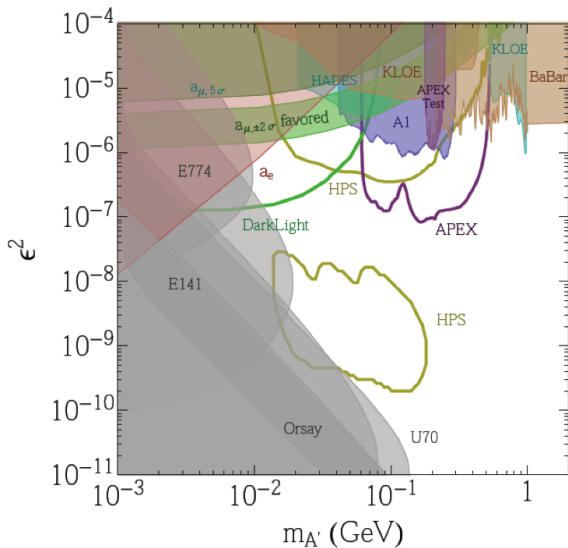
- DarkLight is a proposed experiment:
- Searching in the lowest dark photon mass regime: 10-100 MeV/c<sup>2</sup>
- Could resolve  $(g - 2)_\mu$ : much of preferred region excluded at higher masses
- Will utilize the 100 MeV  $e^-$  beam of the Jefferson Lab Free-Electron Laser incident on a H<sub>2</sub> gas target
- Model-independent, kinematically-redundant exclusive search

# DarkLight Parameter Space: 10-100 MeV/c<sup>2</sup>



Gray: excluded by theory/experiment  
Green: favored to resolve muon g-2 anomaly

# Comparison of Experiments



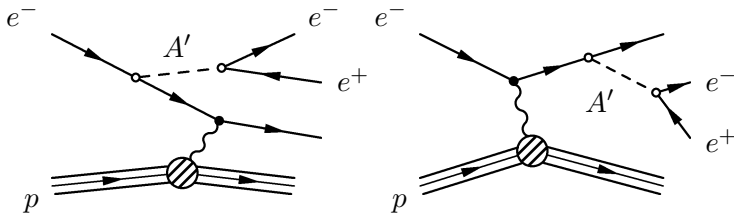
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# Dark Interactions in e-p Collisions

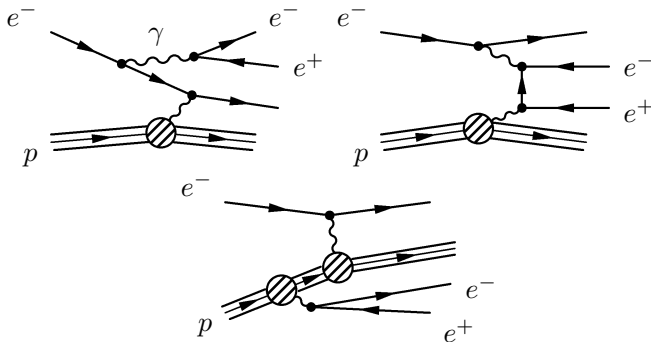
DarkLight will search for a dark photon in electron-proton scattering



- Reconstruct tracks of all four final state particles
- Invariant mass of the  $e^+/e^-$  pair gives the mass of the  $A'$

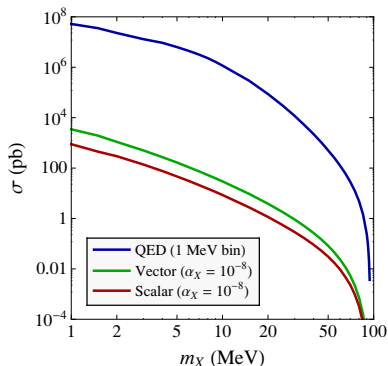
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Backgrounds are enormous!



# Dark Interactions in e-p Collisions

Backgrounds are enormous!



Small resonance on an already rare process

→ need exceptionally high luminosity

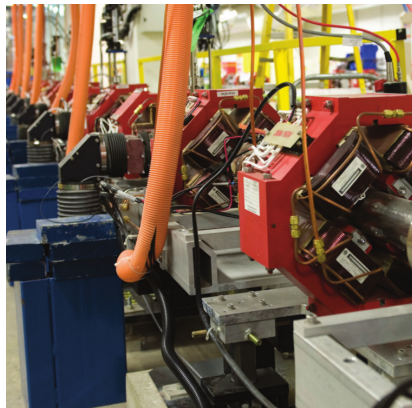
$$\rightarrow \mathcal{L} = 2 \times 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$$

Goal:  $1 \text{ ab}^{-1}$  in one week

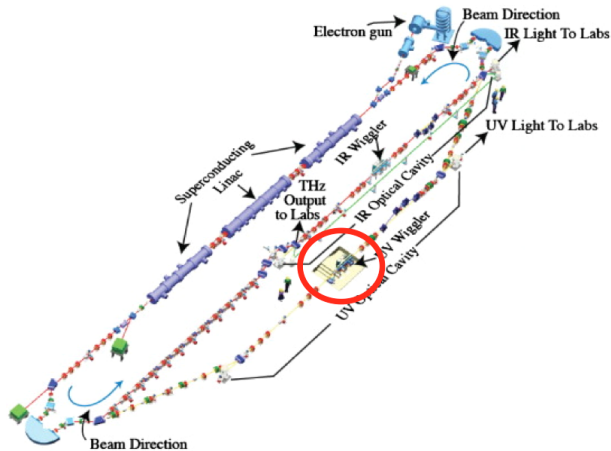


# The Jefferson Lab Free Electron Laser

- Next-generation Energy Recovering Linac (ERL)
- 100 MeV, 10mA  
→ **1 MW of power**
- Provides intensity necessary to observe a dark photon



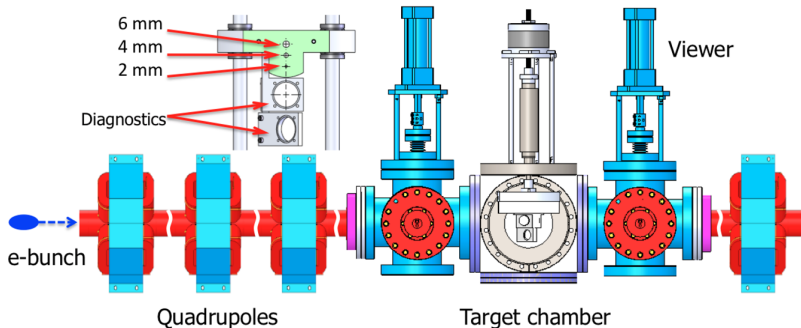
# JLab FEL Layout



DarkLight can be installed in the UV wiggler pit

# ERL Beam Test, July 2012

Megawatt 100 MeV  $e^-$  beam through a 2mm aperture



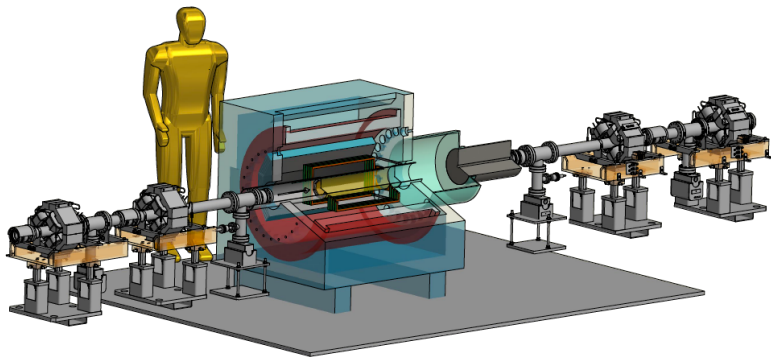
- Only ppm losses over 7h
- FEL has the stability required for DarkLight
- PRL (111, 164801), October 2013

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# The DarkLight Experiment



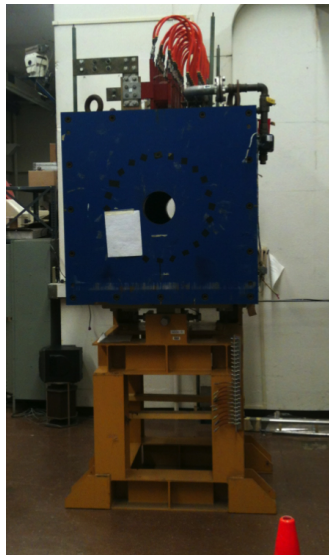
Proposed Phase 1 Layout

- 100 MeV  $e^-$  on an internal gas  $H_2$  target in 0.5T solenoid
- Silicon recoil proton detector inside target chamber
- Target chamber surrounded by lepton tracker

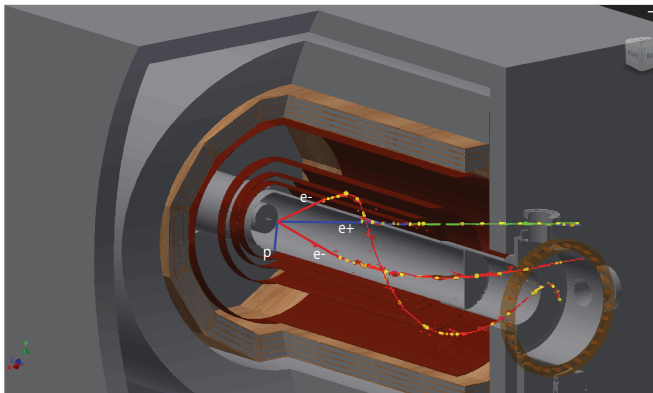
# Magnetic Field

Existing solenoid from E906 at BNL

- 0.5 T solenoid with rectangular yoke
- Inner diameter  $\sim 70\text{cm}$
- Currently located at Stony Brook University



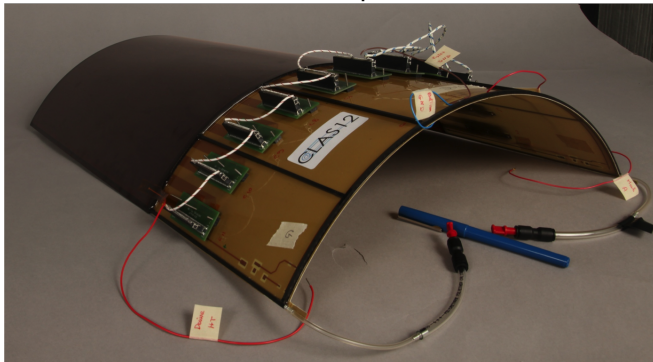
## Four cylindrical tracking layers



Constraints: thin, capable of handling high rates

# MicroMegas

Pursuing the use of “Micro-Mesh Gaseous Structures”  
– **MicroMegas** –  
as tracker planes



New tracking technology being developed at CEA-Saclay

- Similar to GEMs, but more robust
- Installation underway at CLAS (JLab) for 12 GeV upgrade



With this detector, can also measure:

- Elastic e-p cross-section at high  $\theta$  and low  $Q^2$   
→ **proton magnetic radius**
- $A'$  invisible decays

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Developing:

- Track reconstruction at high rates
- Detectors, DAQ, and software to perform this tracking

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Simulations to:

- Analyze signal and backgrounds
- Prepare tracking and reconstruction software

Goal → have algorithms prepared in advance

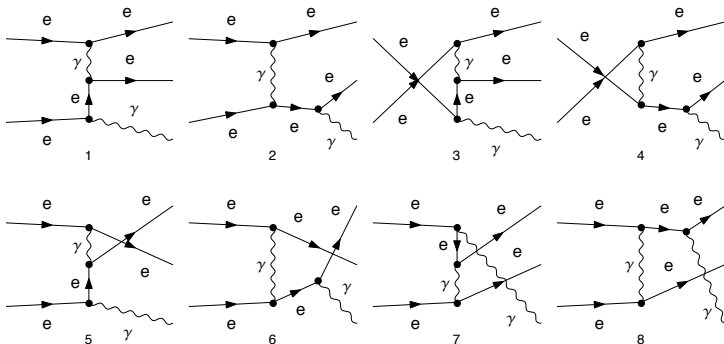
Physics processes:

- Signal and QED background
- Elastic electron-proton scattering
- Møller scattering
- Radiative processes

# Development of a Radiative Møller Generator

DarkLight has exceptionally high background rates, including radiative processes

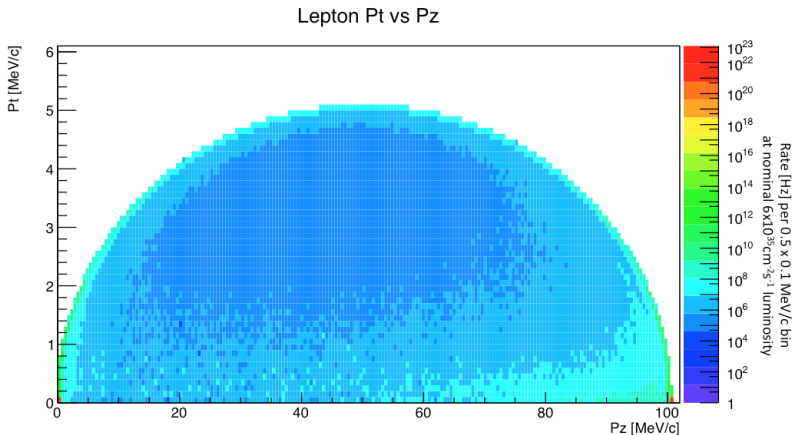
- A radiative Møller/Bhabha event generator is under development



# Development of a Radiative Møller Generator

Covers full photon kinematic phase-space:

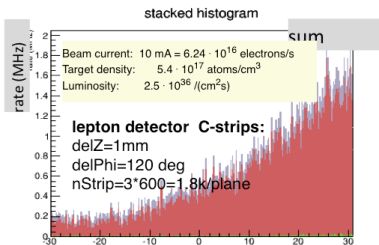
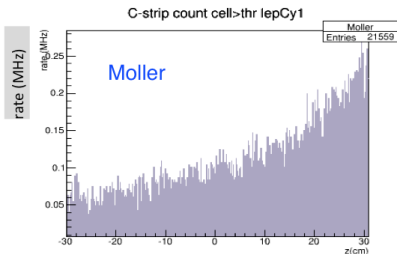
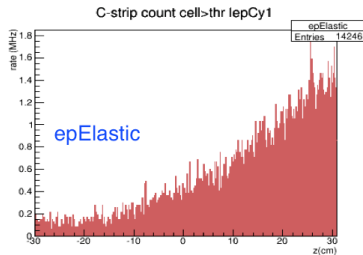
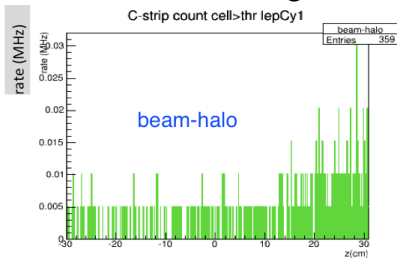
- Elastic e-e events with soft corrections (Tsai, 1960)
- Hard single-photon bremsstrahlung events



Paper in preparation; code will be made available

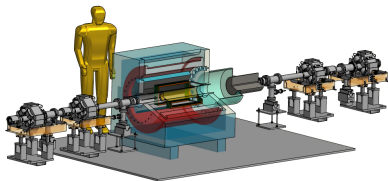
# Lepton Tracker Rates

Total integrated rates:  $\mathcal{O}(100)$  MHz



Segmentation of detector reduces readout rates to  $<2\text{MHz}$

Streaming DAQ enables high-rate readout



- Stream  $50k \times 1$  Byte channels at 40 MHz
- **2 TB/sec raw data input rate**



- Make “movie” at 40 MHz
- Read pixels in parallel and recombine into frames
- Online analysis picks interesting frames

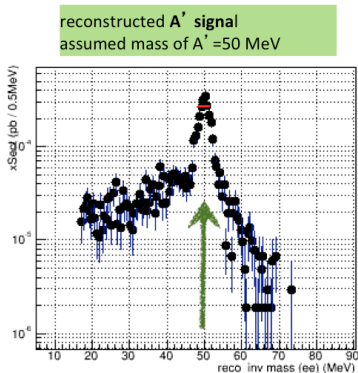
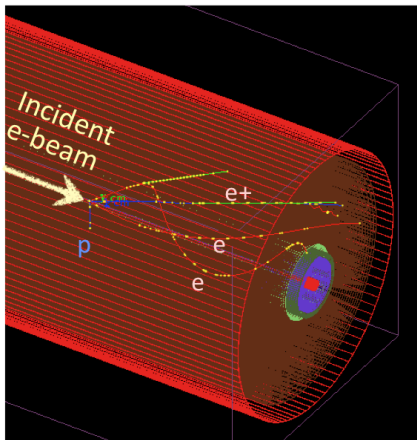
“Trigger and camera”  $\rightarrow$  “Video camera” and post-processing.  
2 TB/sec  $\rightarrow$   **$\mathcal{O}(100)$  MB/sec to disk**



# Tracking and Reconstruction

Tracking and reconstruction algorithms in development<sup>1</sup>

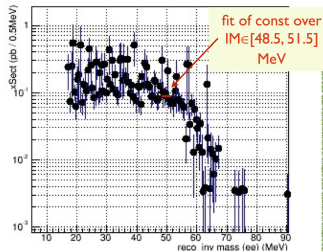
$e p \rightarrow e^- p A' (50 \text{ MeV}) \rightarrow e^+ e^-$



<sup>1</sup>J. Balewski, R. Corliss, R. Cowan

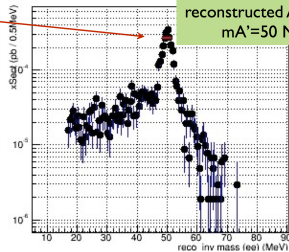
# Event reconstruction studies

reconstructed QED events  $W_{imCut2}$

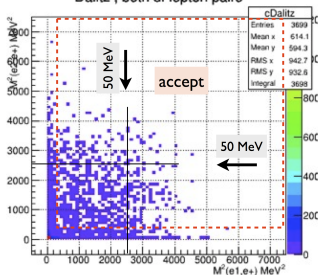


reco  $IM(e^+e^-)$  both lept.pairs, final  $W_{imCut2}$

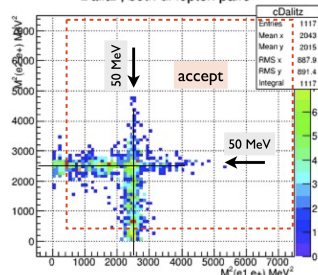
reconstructed  $A'$  events  
 $m_{A'} = 50$  MeV



Dalitz, both di-lepton pairs



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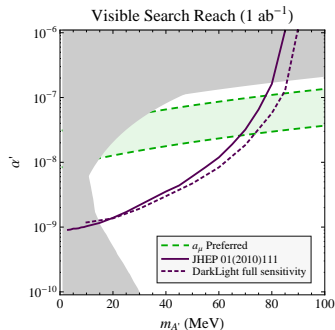


# Status of Realization

- **Full scientific approval from Jefferson Lab received in June, 2013**
- January, 2014: NSF MRI proposal submitted for Phase 1 (2015)
- Work in progress to finalize full design by summer 2014

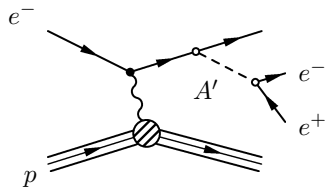
# Summary

- Dark photon search in 10-100 MeV/ $c^2$  range
- Could explain the  $(g - 2)_\mu$  anomaly



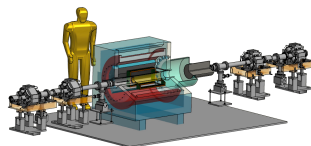
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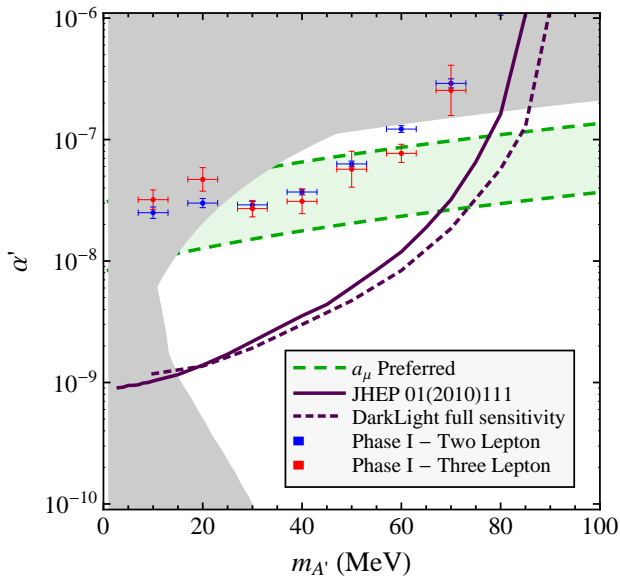


# Summary

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- Precision test of the process  $ep \rightarrow epe^+e^-$
- If Phase 1 funding received  $\rightarrow$  2015
- Full, Phase 2 experiment could take place in 2017



# DL Phase 1 Reach





# DL Invisible Reach

